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Soft X-ray Performance of High-Resolution X-ray Spectrometers Based on Superconducting Tunnel Junctions

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Abstract

We are developing cryogenically-cooled, broad-band, high-resolution X-ray spectrometers based on superconducting tunnel junction (STJ) sensors for applications in astrophysics, material science and biophysics. Such cryogenically-cooled STJ detectors operating at temperatures of a few 100 mK can operate at count rates approaching those of ionization-based semiconductor detectors while providing an order of magnitude better energy resolution for soft X rays. Here we describe recent advancements and present experimental results obtained with some of our STJ detector prototypes operated at beamlines of the Stanford Synchrotron Radiation Laboratory (SSRL).

Using a monochromatized synchrotron beam at SSRL to directly irradiate our detectors we studied the detector response as function of energy and count rate and demonstrated their high count rate capability and good energy resolution. With a 141 μm x 141 μm Nb-Al-Al_2O_3-Al-Nb superconducting tunnel junction detector we achieved an energy resolution of 5.9 eV (FWHM) and an electronic noise of 4.5 eV (FWHM) for 277 eV X rays and count rates of several 100 counts per second (cps). Increasing the count rate, the resolution at 277 eV remained below 10 eV for count rates up to ~10 000 cps and then degraded to only 13 eV at 23 000 cps.

Our detectors exhibited similar performance measuring fluorescence X-rays from samples containing transition metals and low-Z elements excited by the synchrotron beam. In those SR-XRF measurements we obtained a FWHM energy resolution of 6 - 15 eV for X rays in the energy range between 180 eV and 1100 eV and count rates of several 1000 cps. These results show that such detectors will prove very useful in X-ray fluorescence analysis and microanalysis applications.

Finally, we will describe our approaches to extend the useful energy range of these detectors to higher X-ray energies, to increase the detector area and to develop a compact, inexpensive detector system for practical applications.

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